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FORCE TESTS OF A SLOTTED SEMISPAN DELTA WING MODEL AT HYPERSONIC MACH NUMBERS

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**Glenn H. Merz
ARO, Inc.**

April 1968

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FOREWORD

The work reported herein was done at the request of the Air Force Office of Scientific Research (AFOSR) for Aerospace Research Associates (ARA), Inc., West Covina, California, under Program Element 6244501F, Project 9781, Task 978101.

The test results presented herein were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee, under Contract AF40(600)-1200. The tests were conducted from December 6 to 13, 1967, under ARO Project No. VT0640. The manuscript was submitted for publication on February 2, 1968.

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This technical report has been reviewed and is approved.

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ABSTRACT

Tests were conducted to determine the effect of slots on the aerodynamic characteristics of a semispan 70-deg swept delta wing. The purpose of the slots was to reduce the model viscous drag by bleeding off the windward surface boundary layer. Data were obtained at nominal Mach numbers of 6 and 10 at free-stream Reynolds numbers, based on wing root chord, of 15.2×10^6 and 6.4×10^6 and angles of attack from -2 to 14 deg. Selected test results are presented and illustrate that the effects of the slots and Reynolds number variation were small.

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NOMENCLATURE

C_D	Forebody drag coefficient, drag/ $q_\infty S$
C_L	Lift coefficient, lift/ $q_\infty S$
L/D	Lift-to-drag ratio
M_∞	Free-stream Mach number
p_o	Tunnel stilling chamber pressure, psia
p_o'	Stagnation pressure downstream of a normal shock, psia

p_t	Probe pressure, psia
q_∞	Free-stream dynamic pressure, psia
Re_c	Free-stream Reynolds number based on wing root chord (48.00 in.)
S	Model reference area, 419.29 in. ²
T_o	Tunnel stilling chamber temperature, °R
x	Chordwise distance from spanwise gap, in., positive upstream, see Fig. 1
y	Spanwise distance from root chord, in., see Fig. 1
z	Distance from model surface, in., see Fig. 1
α	Model angle of attack, deg, see Fig. 1

SECTION I INTRODUCTION

A theoretical and experimental program is being conducted by ARA, Inc., to determine the maximum lift-to-drag ratios of various delta wing configurations at supersonic Mach numbers. Previous AEDC support of this program is reported in Ref. 1. Extension of the scope of this program to include evaluation of the effects of both spanwise and chordwise slots on the wing aerodynamic characteristics resulted in the present tests. The purpose of the slots was to reduce the model viscous drag by bleeding off the windward surface boundary layer, thereby increasing the lift-to-drag ratio.

The tests were conducted in the 50-in. hypersonic tunnels (Gas Dynamic Wind Tunnels, Hypersonic (B) and (C)) of the von Kármán Gas Dynamics Facility (VKF) at nominal Mach numbers of 6 and 10 and Reynolds numbers, based on wing root chord, of 15.2×10^6 and 6.4×10^6 .

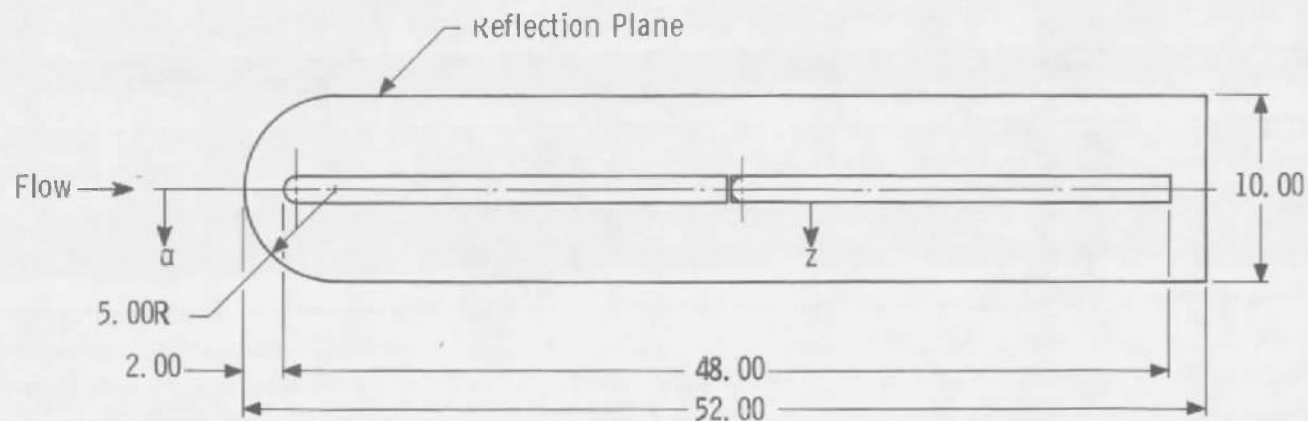
SECTION II APPARATUS

2.1 MODEL AND SUPPORT EQUIPMENT

The stainless steel model (Fig. 1), supplied by ARA, Inc., was a semispan 70-deg delta wing with a 48-in. root chord and cylindrical leading edge. The model consisted of two tip panels, triangular in shape, each of which comprised 25 percent of the projected total wing area, and a rectangular main wing panel. A reflection plane was mounted between the model and support strut with a nominal gap of 0.030 in. between the reflection plane and root chord of the model.

To eliminate the alignment problems reported in Ref. 1, the model was mounted vertically on a support system designed and built by VKF. The lower portion of this system housed a motor-driven pitch mechanism that rotated the strut, reflection plane, and model as a unit. Configuration changes were made by varying the slot width between the tip panels and the main wing panel. A photograph of the model and its mounting apparatus is shown in Fig. 2.

A pitot-pressure probe was used for model boundary-layer surveys. The probe was a 0.0625-in. -OD by 0.011-in. -thick-wall stainless steel tube formed to an elliptical cross section with a height of 0.040 in.



All Dimensions in Inches

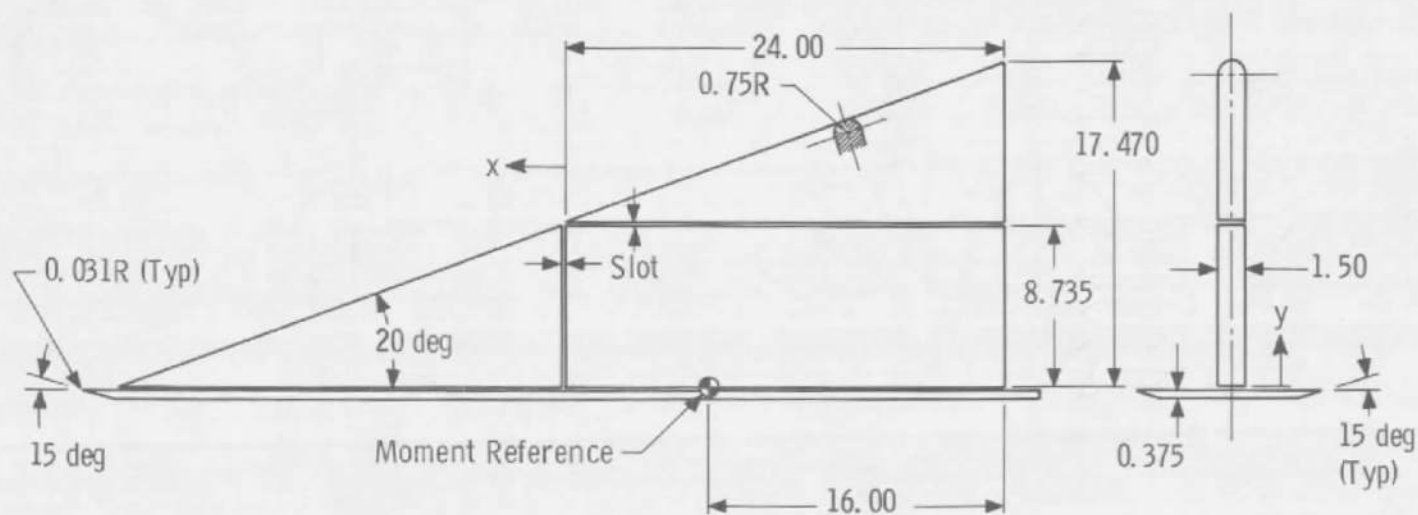


Fig. 1 Model Details

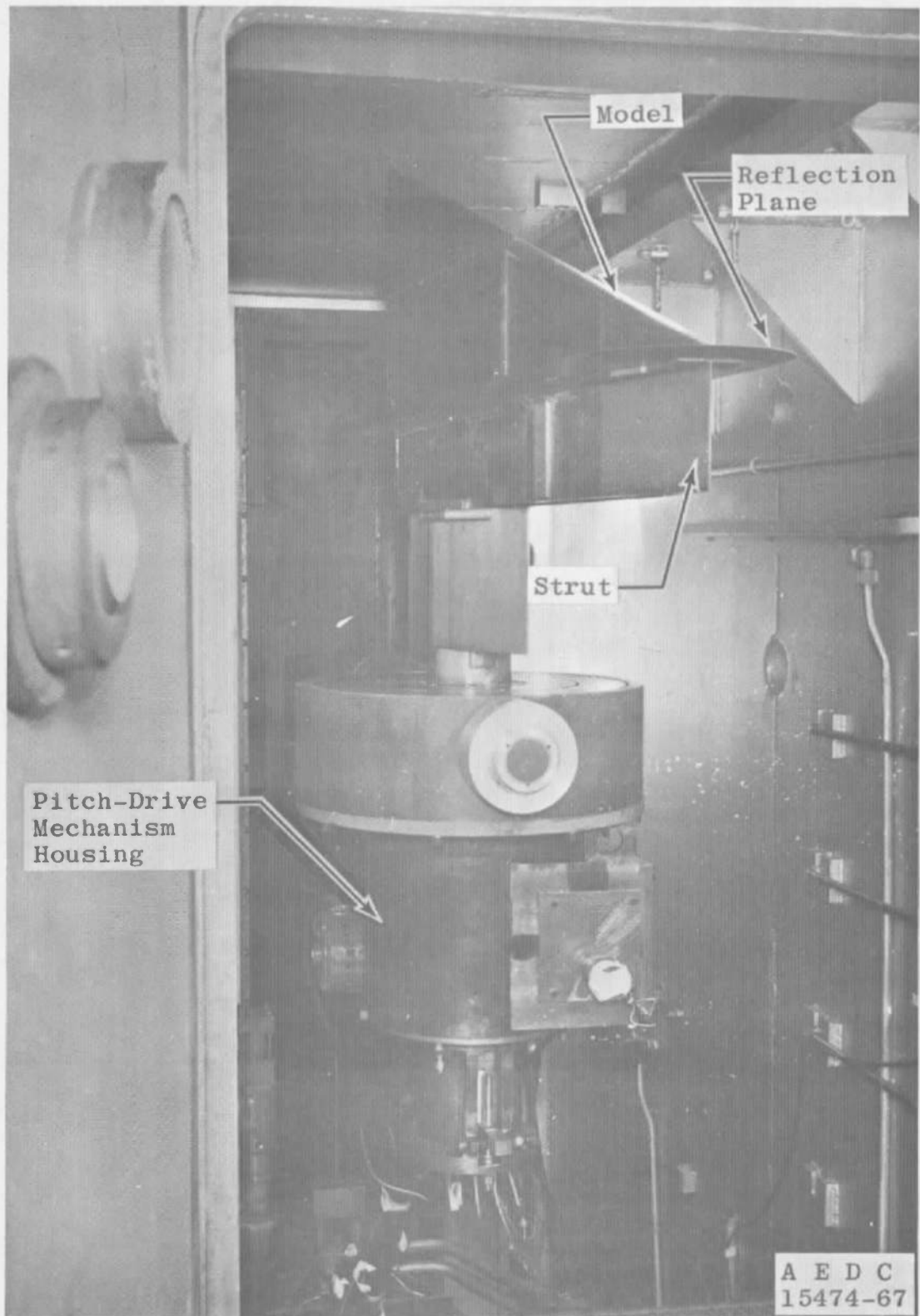


Fig. 2 Model Installation Photograph

2.2 WIND TUNNELS

Tunnels B and C are continuous, closed-circuit, variable density wind tunnels with axisymmetric contoured nozzles and 50-in.-diam test sections. Tunnel B operates at a nominal Mach number of 6 or 8 at stagnation pressures from 20 to 300 and from 50 to 900 psia, respectively, at stagnation temperatures up to 1350°R. Tunnel C operates at a nominal Mach number of 10 or 12 at stagnation conditions from 200 to 2000 psia at 1900°R and from 600 to 2000 psia at 2400°R, respectively. The model may be injected into the tunnels for a test run and then retracted for model cooling or model changes without interrupting the tunnel flow. A description of the tunnels may be found in Ref. 2.

2.3 INSTRUMENTATION

Model forces and moments were measured with a five-component, moment-type, strain-gage balance supplied and calibrated by VKF. Before the test, combined balance static loadings were applied, simulating the model loading range anticipated during the test. The uncertainties listed below correspond to the differences between the applied loads and the values calculated by the final data reduction balance equations. Since the balance was mounted vertically in the tunnel, the balance components listed correspond to the model component measured and are not the balance components normally used to obtain these forces and moments.

<u>Balance Component</u>	<u>Design Load</u>	<u>Maximum Static Loads</u>	<u>Uncertainties</u>
Normal force, lb	500	500	±1.3
Pitching moment, in. -lb	1200	640	±1.1
Axial force, lb	100	100	±0.4

Model base pressure was measured with a 1-psid transducer to within ±0.0002 psia or ±1 percent, whichever was greater. A base axial-force correction was made for the wing base area (25.964 in.²). Model pressures in the vicinity of the slots were measured in Tunnel B with 15-psid transducers and in Tunnel C with 1-psid transducers. The estimated Tunnel B pressure measurement precision was ±0.003 psia or ±0.5 percent, whichever was greater, and estimated Tunnel C measurement precision was ±0.001 psia or ±0.5 percent, whichever was greater.

Pitot pressures were measured with a 15-psid transducer to within ±0.003 psia or ±1 percent, whichever was greater.

SECTION III PROCEDURE

A summary of the configurations tested and the tunnel conditions at which the tests were conducted is given in Table I.

**TABLE I
TEST SUMMARY**

M_∞	$P_{O'}$ psia	$T_{O'}$ °R	$Re_c \times 10^{-6}$	q_∞ psia	$P_{O'}$ psia	Slot Width, in. (1)	α , deg	Type of Test
6.01	80	820	6.4	1.3	2.4	0.000, 0.015, and 0.030	-2 to 14	Force
6.04	200	830	15.2	3.1	5.8	0.000 and 0.045	7	Boundary-Layer Survey
↓	↓	↓	↓	↓	↓	0.000, 0.015, 0.020, 0.030, 0.045, and 1/2 open at 0.015(2)	-2 to 14	Force
10.20	1200	1830	6.4	1.8	3.3	0.000 and 0.015	7	Boundary-Layer Survey
↓	↓	↓	↓	↓	↓	0.000, 0.015, 0.020, 0.030, and 0.045	-2 to 14	Force

NOTES: (1) Chordwise and spanwise slot widths were equal for all configurations.

(2) Half of each slot nearest the leading edge was closed for this configuration

SECTION IV RESULTS AND DISCUSSION

A summary of the Mach 6 lift and drag characteristics is presented in Fig. 3. These data are representative of all configurations and test conditions since the effects of slot width and Reynolds number variation were within the measurement precision. The pressure drag produced by the blunt leading edge was estimated to be approximately ten times the wing viscous drag, and a small decrease in viscous drag (if present) could not be detected. Estimates of the wing lift and drag coefficients using Newtonian theory for the leading edge (Ref. 3), wedge tables for the windward side of the model, and a Prandtl-Meyer expansion of the free-stream flow for the leeward side were in good agreement with the data.

The Mach 10 lift and drag characteristics (Fig. 4) were invariant for all configurations and in reasonable agreement with the predictions. Drag estimates for both Mach numbers were slightly lower than test data because the theory does not include viscous drag.

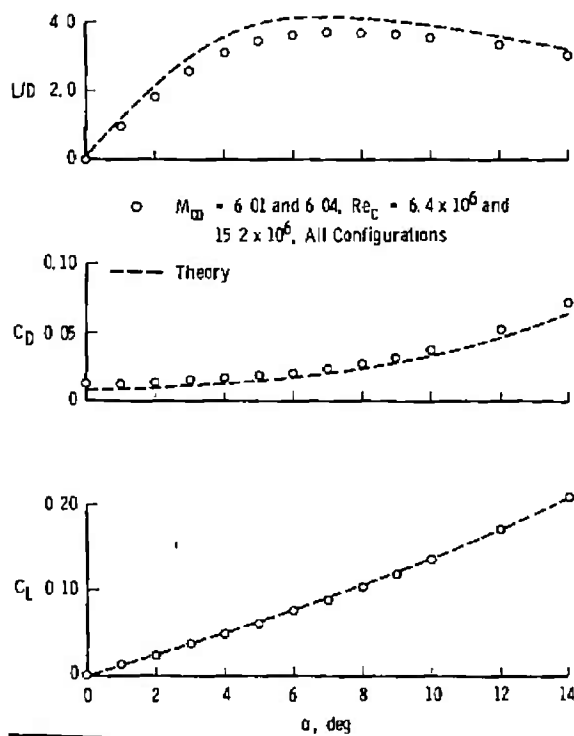


Fig. 3 Mach 6 Lift and Drag Characteristics

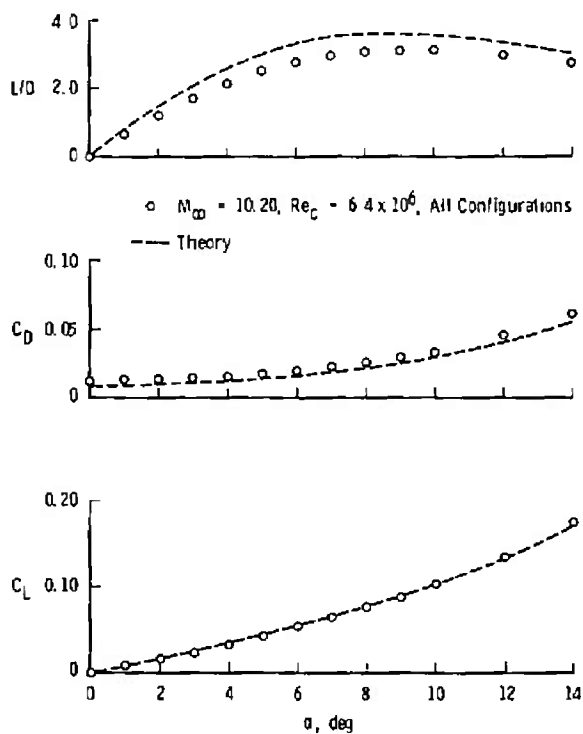


Fig. 4 Mach 10 Lift and Drag Characteristics

Boundary-layer profiles are presented in Fig. 5 for the leeward side of the model at 7-deg angle of attack. At Mach 6, the boundary layer 5 in. forward of the spanwise slot exhibited the flat pitot-pressure profile near the model surface characteristic of laminar boundary layers. The Mach 6 pitot-pressure profiles 3 in. downstream from the slot indicated a turbulent boundary layer both with the slot closed and with the maximum slot width (0.045 in.). The major effect of the flow through the slot was a disturbance in the flow field about 1.25 in. from the model surface. There was no indication of a turbulent boundary layer at Mach 10; however, as expected with the reduced Reynolds number, the boundary layer was noticeably thicker.

Sym	M_∞	$Re_c \times 10^{-6}$	x , in.	y , in.	Slot Width, in.
○	6.04	15.2	5.0	4.0	0.045
□	6.04	15.2	-3.0	4.0	0.000
◇	6.04	15.2	-3.0	4.0	0.045
△	10.20	6.4	-3.0	4.0	0.000

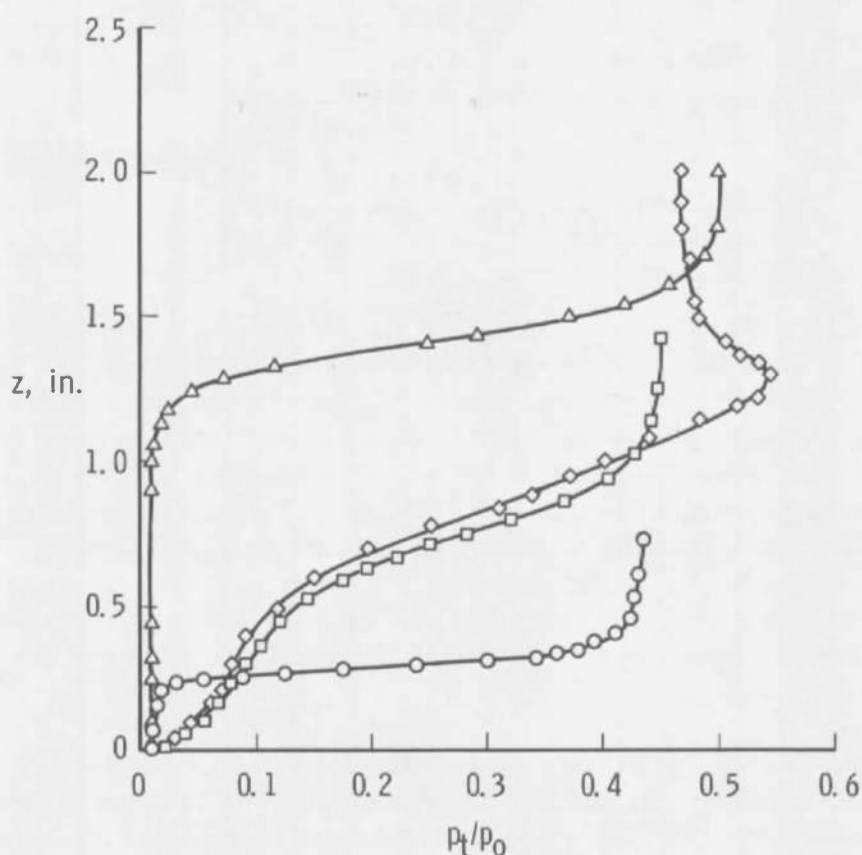


Fig. 5 Boundary-Layer Profiles

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boundary layer bleed

1. Triangular wing -- Hypersonic flow

2 " " -- Boundary layer bleed

3 " " -- Aerodynamic characteristics

4 Slatted wings

1-1